USE OF TEMPERATURE ACCUMULATIONS AS AN INDEX TO THE TIME OF APPEARANCE OF CERTAIN INSECT PESTS DURING THE SEASON

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It has long been a matter of common observation that insects are very sensitive to temperature. As the cold of winter approaches many perish, and others go into hibernation to await the warmth of spring. In the spring they are aroused from hibernation and pursue their normal course of feeding, reproducing, and developing when the temperature rises to about 50° F., becoming more active as the season advances and the temperature rises until it reaches the optimum temperature for development in midsummer, when the rate of development is at its highest point. Above this point the torrid heat of summer is unfavorable for development of some species, resulting in the slowing up of their activities and development. As the temperature rises still higher, many go into estivation and others succumb to the intense heat.

In recent years many investigations have been conducted to determine more definitely the relation between temperature and rate of development in insects. The writer in 1915-16-17 collected data on the development of the stages of the codling moth, the life history, and the progress of the seasonal history, and sought to relate the temperature to rate of development and the accumulation of temperature units to progress of development, using out-of-doors temperatures in making the correlation.

The purpose of this paper is to explain briefly how temperature units may be used to forecast the date when any stage of an insect pest may be expected to appear, and to do so long enough in advance of its appearance to enable the grower of crops to take proper steps to ward off threatened injury.

In this latitude, temperatures range from about —30° to about 115° F. The range between these extremes may be divided into six zones, based on the reaction of insects to different degrees of temperature, as indicated below.

6. **High Fatal Zone**............	Fatality due to heat.
5. **Estivating Zone**............	Not fatal, but unfavorable for development.
4. **Retarding Temperature Zone.**	Rate of development decreasing with rise of temperature.
Temperature of maximum rate of development.	
3. **Effective Temperature Zone.**	Rate of development increasing with rise of temperature.
Zero of development.	
2. **Hibernating Zone**............	Not favorable for development due to lack of heat.
1. **Low Fatal Zone**............	Fatality due to lack of heat.

In these studies we are interested in the zones of effective temperature and retarding temperature, the relation of different temperatures to the development of the different stages and to seasonal development of insects.

Studies of the codling moth revealed that the rate of development in all its stages varied almost directly as the rise and fall of temperature within the zone of effective temperatures. Other investigators, by the use of apparatus for controlling temperature and humidity, have ascertained that changes in temperature near the zero of development have a slightly less value in producing change in rate of development and that similar changes in temperature near the upper part of the zone of effective temperatures have a slightly greater value, than do like changes in temperatures near the middle of the zone. They also have determined that humidity has a slight effect on the rate of development and on the zero of development, but these can not be detected by the use of varying out-of-door temperatures and it is unnecessary to take account of them for practical purposes. In these studies, therefore we are assuming that within the effective temperature zone the rate of development varies as the temperature.

It was also found that when the temperature rises above the point at which the maximum rate of development is reached, the rate of development was retarded approximately as it would be if the temperature had fallen a like amount below that point, and although this may not be quite accurate, it is assumed to be sufficiently accurate for our purpose. This relation enables us to convert retarding temperatures into equivalent effective temperatures, as the rate of development at two, three, or four degrees above the temperature of the maximum rate of development is approximately the same as at a temperature of two, three, or four degrees below that point. If, for instance, the temperature of the maximum rate of development of the pupa of the codling moth is 87° F., the rate of development of the pupa would be approximately the same at 90° F. as it would be at 84° F.

The limiting point between the hibernating zone and the effective temperature zone is called the zero of development. It is the temperature at which development ceases when the temperature falls and at which development begins when the temperature rises from hibernating temperatures.

The limiting temperature between the effective temperature zone and the retarding temperature zone is the temperature at which development proceeds at its highest rate.

These two points may differ for different insects and for different stages of the same insect.

The limits of the various zones have not been determined definitely for any insect, but the zero of development is in the neighborhood of 50° F. and the temperature of the maximum rate of development is probably between 85° and 90° F.

For the codling moth the zero of development for the larva and egg is near 50° F. and for the pupa 52° F.; the degree of the maximum rate of development for the egg, larva. and pupa respectively is near 88°, 85°, and 87° F.

The units of temperature accumulation used in this investigation are the day-degree and the effective day-degree. A day-degree is a unit of one degree operating for one day. An effective day-degree, or a day-degree of effective temperature, is a day-degree measured by temperatures within the effective temperature zone.

The day-degrees which accumulate above any temperature used as the zero for any day are the same as the average of the hourly temperatures above that zero.

To compute the effective day-degrees for any day during which the temperature does not at any time rise above the temperature of the maximum rate of development, add the hourly temperature readings for the day above the zero of development, and divide by 24, or add the hourly readings for each alternate hour and divide by 12.

To compute the effective day-degrees which accumulate during a day when the temperature for part of the time is above the temperature of the maximum rate of development, subtract from the average day-degrees above the zero of development, twice the average day-degrees above the degree of the maximum rate of development. The result will be the day-degrees of effective temperatures, or the number of effective day-degrees which accumulated during the day, and will serve as a quite accurate index to the value of the day in furthering the development of any stage of the insect or its life, or seasonal history.

The formula for the effective day-degree accumulations for any day may be written, x = a — 2b, in which "a" is the average of the hourly temperatures for the day above the zero of development, and "b" is the average of the hourly temperatures for the day above the degree of the maximum rate of development.

The following table illustrates the relation of temperature to the incubation period of the codling moth, the zero development being 50° F. and the degree of maximum rate of development 88° F.

TABLE I.

TEMPERATURE AND THE INCUBATION PERIOD OF THE CODLING MOTH

No. Obs.	Period in Days p	Mean Daily Tem. deg. F.	Average daily day-degrees			Total day-degrees	
			(50+) a	2(88+) 2b	(50+)-2(88+) a-2b	50+ ap	(50+)-2(88+) (a—2b)p
46	14.00	61.60	12.30		12.30	172	172
229	12.67	63.11	13.31		13.31	170	170
622	10.66	64.94	15.13		15.13	161	161
305	9.35	67.48	17.47		17.47	163	163
595	8.67	69.01	19.01		19.01	165	165
515	7.72	71.33	21.33		21.33	165	165
572	7.00	73.12	23.12	.01	23.11	162	162
335	6.60	74.86	24.86	.45	24.41	164	161
232	6.02	77.43	27.43	.96	26.47	165	159
249	5.95	78.71	28.71	.96	27.25	171	165
288	5.71	80.14	30.14	1.93	28.21	172	161
141	5.52	82.86	32.86	3.74	29.12	181	161
46	5.53	84.00	34.00	4.66	29.34	188	162
4175	7.67		21.70		21.33	166	163

Column 4 gives the average day degrees above 50° F. for the period (a); column 5 gives twice the average daily day-degrees above 88° F. (2b); and column 6 gives the remainders left after subtracting the retarding day-degrees in column 5 from the corresponding day-degrees in column 4, or the average daily effective day-degrees for the period (a—2b).

The periods (p) are given in column 2. Column 7 gives the products of corresponding numbers in columns 2 and 4, or the total day-degrees which accumulated above 50° F. during the period at the various temperatures (ap). Notice the wide variation in the numbers in column 7, and that the last four numbers in column 7 increase above the average at the higher temperatures. This is due to the fact that column 4 includes some retarding day-degrees.

Column 8 records the products of the corresponding numbers in columns 2 and 6, or the average effective day-degrees which accumulated during the incubation period at the different temperatures (a—2b) p. The difference between columns 7 and 8 is that the proper corrections were made in 8 for retarding temperatures above 88° F. whereas no correction was made in computing column 7.

The formula for the incubation period may be given as (a—2b) p= c=163, in which "c" is the average total number of effective day-degrees which accumulates during the period, or the so-called thermal constant for the period. It will be noticed that the variation from the average number of accumulated day-degrees at the different temperatures is very slight.

A practical application of the relation disclosed in Table 1 may be illustrated as follows:

It was observed that the first adults of the codling moths were emerging in an orchard May 11, 1915, at Olney. We did not know it then, but it is now known that about 50 effective day-degrees accumulate before egg-laying begins, and that 163 more accumulate before the eggs hatch, and that the average daily accumulation of effective day-degrees at Olney at that time in the season is 15. Therefore, by solving the simple problem, $(50 + 163) \div 15 = 14$, we might have determined that 14 days after May 11, or May 25, the first larvae would be hatching in the orchard. With this information, the orchardman could have had 14 days in which to plan to have the first cover spray on his trees by May 25. In this particular instance the first larvae were observed to be hatching on May 25. We can not always expect to forecast the date that closely. If the weather during the period should be colder or warmer than normal, the date of hatching would be delayed or hastened a day or two, but if the weather is normal, the predicted date will usually coincide with the actual date.

For the last few years the information furnished to the orchardmen of Illinois each spring by Mr. W. P. Flint of the Natural History Survey Division as to the time when the first cover spray for the codling moth should be applied, has been obtained by this method, and has proved very useful and accurate.

The following table illustrates the relation of temperature to the larval period of the codling moth, the zero of development being at 50° F. and the maximum rate of development at 85° F.

TABLE II.
TEMPERATURE AND THE LARVAL PERIOD OF THE CODLING MOTH

No. Larvae	Periods in Days p	Mean Daily Temp.	Daily day-degrees			Total Day-degrees	
			50+ a	2(85+) 2b	(50+)−2(85+) a−2b	50+ ap	(50+)−2(85+) (a−2b)p
22	35.57	69.45	19.45	.34	19.11	692	680
122	32.29	70.88	20.88	.30	20.58	674	665
45	29.20	73.48	23.48	.72	22.76	686	665
33	28.62	74.53	24.53	.74	23.79	702	681
14	27.14	76.74	26.74	1.40	25.34	726	688
20	25.93	79.39	29.39	3.62	25.77	762	668
78	26.33	80.30	30.30	4.36	25.94	798	683
344	29.07	74.31	24.31	1.56	22.75	719	673

The same method was followed in analyzing the data on the larval period. The approximate zero of development was found to be 50° F. and maximum development was found to occur at 85° F. Column 4 gives the average daily day-degrees above 50° F. (a); column 5 gives twice the number of day-degrees above 85° F. which must be subtracted from day-degrees in column 4 to make correction for the retarding temperatures above 85° F. (2b); and column 6 gives the corrected day-degrees above 50° or the average daily effective day-degrees for the period (a—2b). Columns 7 and 8 are the products respectively of columns 2 and 4 (ap) and columns 2 and 6 ([a—2b]p). The total day-degrees shown in column 8 are quite uniform in number for different temperatures. The variations are greater than the totals in the corresponding column of Table I, but the larval period is much longer than the incubation period, and there is a correspondingly greater variation in the larval periods than in the incubation periods, and also the number of larvae under observation was much smaller than the number of eggs.

The formula for the average larval period for larvae reared in apples on the tree may be written: $(a-2b)p = c = 673$. It is interesting to note in this connection that the formula for the larval period for larvae reared in picked apples, based on the rearing of 214 larvae, is $(a-2b)p = c = 587$, of 86 day-degrees less than for larvae reared in apples on the tree, showing that the character of the food materially affects the rate of development. A difference of 86 effective day-degrees in the total is equivalent to a difference of about 4 days in the length of the period.

Table III shows the relation of temperature to the pupal period of the codling moth, the zero of development being at 50° F. and 52° F. and the maximum rate of development at 87° F.

TABLE III

PUPAL PERIOD OF THE CODLING MOTH

Summary on Relation of Temperature to Development

No. of observations	Periods in days p	Average mean daily temperatures	Average daily day-degrees					Total day-degrees			
			50+ a	52+ a′	2(87+) 2b	(50+)—2(87+) a—2b	(52+)—2(87+) a′—2b	50+ a′p	52+ a′p	(50+)—2(87+) (a′—2b)p	(52+)—2(87+) (a′—2b)p
2	45.50	52.60	6.19	5.19	....	6.19	5.19	281.6	236.0	281.6	236.0
348	35.20	55.70	7.85	6.80	....	7.85	6.80	276.3	237.9	276.3	237.9
976	34.01	56.15	8.24	7.08	....	8.24	7.08	280.2	240.8	280.2	240.8
243	27.77	58.50	9.92	8.69	....	9.92	8.69	275.5	241.3	275.5	241.3
218	13.80	69.28	19.27	17.31	....	19.27	17.31	265.9	238.9	265.9	238.9
175	12.70	70.79	20.79	18.79	.04	20.75	18.75	264.0	238.6	263.5	238.1
221	11.51	73.11	23.11	21.11	.24	22.87	20.87	266.0	242.8	263.2	240.2
247	10.73	74.92	24.92	22.92	.42	24.50	22.50	267.4	245.9	262.9	241.4
517	10.02	76.77	26.77	24.77	.88	25.89	23.89	268.2	248.2	259.4	239.4
481	9.44	79.14	29.13	27.13	1.63	27.50	25.50	275.0	256.1	259.6	240.7
133	9.43	80.88	30.88	28.88	3.52	27.36	25.36	291.1	272.2	257.9	239.0
256	9.24	82.68	32.68	30.68	4.12	28.56	26.56	302.0	283.5	263.9	245.4
3817	14.49	......	19.03	17.38	.77	18.26	16.61	275.6	251.8	264.6	240.7

The same method was followed in analyzing the data on the pupal period as on the incubation and the larval period, except that the results obtained by using both 50° F. and 52° F. as the zero of development are included in this table. The degree of the maximum rate of development for the pupa was determined to be approximately 87° F. Column 11, [(a—2b) p] shows the total effective day-degrees above 50° F. after corrections have been made for temperatures higher than 87° F. and column 12 [(a′—2b) p] shows the same above 52° F.

The fact that in column 11 the total effective day-degrees are much higher at the lower temperatures than at the higher temperatures indicates that 50° F. is below the true zero of development; and the fact that the total effective day-degrees in column 12 are quite uniform in number for all temperatures indicates that 52° F. is near the true zero of development. However, the error will not be great if 50° F. is used as the zero, and as it is much more convenient to use the same zero for the pupa as for the larva and the egg, 50° F. is used in all the computations made. The formula used, therefore, is (a—2b) p= c = 265.

By the use of this table and some simple observations one may forecast very accurately when the first larvae of the second generation of the codling moth will begin to hatch in his orchard. In order to make the observations, the orchardman should put some bands on a number of trees in his orchard, or, preferably, some isolated trees which may be left unsprayed. These bands should be examined daily beginning June 1, until the first larvae are found under them. Then a computation of this kind can be made:

$$3 + \frac{265}{d} + \frac{50 + 162}{d} =$$

number of days after first larvae are found under bands until the first larvae of the second generation will be hatched in the orchard. The "3" in the above statement represents the days that usually elapse before the larvae change to pupae after entering the bands; "d" represents the average daily accumulation of effective day-degrees that normally accumulate during the three weeks following the date when the first larvae are found, and its value may be estimated by reference to the fourth column of Table No. V; 265 is the average number of effective day-degrees that accumulates from the date of pupation to the date of emergence; and $\frac{50 + 162}{d}$ is the average number of days that elapse between the emergence of the moths and the hatching of the young larvae.

Suppose at Urbana the first larvae of the first generation were found under the band June 20. We would proceed as follows to ascertain when to expect the larvae of the second generation to hatch in the orchard. We would first refer to Table V, ascertaining the value of "d" during the three weeks following June 20 to be 23.

$$3 \text{ days (days until larvae will pupate)} +$$

$$\frac{265}{23} \text{ (days until moths will emerge)} +$$

$$\frac{50 + 163}{23} \text{ (days till eggs will hatch)} = 24$$

Twenty-four days after June 20 is July 14. The orchardman would in this case have twenty-four days in which to plan to have the first spray on his trees for the second brood of worms.

This method also has been employed by Mr. Flint in preparing the forecasts sent out to orchardmen as to time to apply the first spray for the second brood of the codling moth.

As mentioned above, the egg, larva, and pupa of the codling moth react somewhat differently to temperature, 50° F. being the approximate zero of development of the egg and the larva, and 52° F. the zero for the pupa, while 88°, 85°, and 87° F. are the approximate temperatures at which the egg, larva, and pupa develop most rapidly. However, if we wish to apply the temperature relations to the whole development period and to the seasonal history, we shall have to select one zero and one degree of the maximum rate of development for all three stages. The most satisfactory zero for all three stages is 50° F. and for the degree of the maximum rate of development 86° F. Table IV gives the results obtained by applying them to the development period which covers the period from the deposition of the egg until the emergence of the adult.

TABLE IV

RELATION OF TEMPERATURE TO THE DEVELOPMENT PERIOD OF THE CODLING MOTH

Generation	Number of observations	Year	Average period	Av. daily effective day degrees	Total effective day degrees
First	74	1915	53.4	21.18	1131
First	65	1916	52.4	21.53	1128
First	104	1917	50.3	22.09	1111
Second	13	1915	49.	22.49	1102
Second	92	1916	44.1	25.35	1118
	348	....	49.34	22.35	1118

Although 1118 was the average number of effective day-degrees which accumulated during the development period, the number of such units which accumulated during the period of individuals within the group varied widely.

The lowest temperature accumulation during this period for any of the individual females was 880 day-degrees but less than 4 per cent of the individuals had accumulations below 950 day-degrees. This latter number may be considered the approximate minimum. As the development period does not include the period which elapses between the time when the adult emerges and the time when she begins to deposit eggs, allow 50 effective day-degrees to cover this time, making in round numbers 1000 as the minimum number of effective day-degrees which accumulate during the entire life cycle from egg to egg. We may therefore expect a new generation of the codling moth for every accumulation of 1000 effective day-degrees that is completed. Observations have corroborated the approximate accuracy of this conclusion.

Thus far the relation of temperature to the egg, larva, pupa, and development periods of the codling moth have been shown, and a method of forecasting the dates when the first larvae of the first generation and the first larvae of the second generation may be expected to appear, by the use of certain observations made in the orchard and the application of the ascertained temperature relations. There is also a relation between temperature and the seasonal history of the codling moth, and time of the appearance of the first individuals of any brood of eggs, larvae, or moths, may be anticipated, even in the absence of definite observations.

To be able to follow the seasonal history of the insect by the use of accumulated temperature units only, it will be necessary to keep a daily record of the effective day-degrees that accumulate, and the total effective day-degrees that have accumulated from the beginning of the season.

By the use of a self-recording thermometer it is a simple matter to compute and record the effective day-degrees above 50°F. that accumulate daily, using the formula, $x = (a - 2b)$, in which "a" represents the average of the hourly readings above 50°F. and "b" represents the average hourly readings above 86°F. Then the total number of effective day-degrees which has accumulated from the beginning of the season up to and including each date may be obtained by adding the accumulation for each day as it is computed to the total accumulation recorded for the preceding day.

When the total accumulation of effective day-degrees approaches 340, one may expect the first adults of the codling moth to be emerging from the overwintering larvae; and when it reaches 550, one may expect the first larvae to be entering the fruit. When it approaches 1342, the first moths of the second brood may be expected to emerge, and when it approaches 1550, the first larvae of the second brood may be expected to hatch in the orchard. In like manner the first adults of the third brood of moths will appear about the time when the sum of effective day-degrees reaches 2342, and the first larvae of the third brood when the sum reaches 2550.

To illustrate a little more clearly the significance of accumulated day-degrees of effective temperature, Table No. V has been prepared, showing the total accumulations from the beginning of the season at Urbana, Illinois, for each day from May 1 to August 31, for the years 1921, 1929, and 1924, also the average daily accumulations and the average total accumulations for each day for the same period, at Urbana, based on 14 years records.

The numbers representing the total effective day-degrees in columns 1, 2, and 3 reflect fairly accurately the advancement in the seasonal history of the codling moth during the years 1921, 1929, and 1924, and the numbers in column 5 show the progress of the seasonal history of the insect in a normal year at Urbana.

If the large differences in the numbers in the horizontal lines after any date for the three years and the average at Urbana are noted, it will be seen how much the seasonal history may vary in different years.

If, for instance, we wish to know how great a variation occurred in 1921, 1929, and 1924, in the dates when the first larvae of the first generation of the codling moth began to hatch in the orchard, we will find in each column the number nearest to 550, and we shall see that the first larvae hatched in 1921 about May 22 or 23; in 1929, May 29 or 30; and in 1924, June 14, and that the normal date at Urbana is June 1. There was a difference of seven days between 1921 and 1929, 16 days between 1929 and 1924, and an extreme difference of 23 days between 1921 and 1924.

Similarly, we might learn something of the variation in dates of the hatching of the first larvae of the second generation in different years by observing the dates on which the accumulations of day-degrees of effective temperature were near 1550. This event occurred theoretically on July 2 or 3 in 1921, July 19 or 20 in 1929, on August 1 in 1924, and it occurs normally on July 19, at Urbana.

The larvae of the third generation began to hatch theoretically on August 11 in 1921, September 5 in 1929, October 4 in 1924; and it begins normally on September 1 or 2 at Urbana.

Column 4 gives the day-degrees of effective temperature which normally accumulate daily at Urbana. It is desirable to know the normal daily accumulations and the total accumulations during the season up to and including each day of the year for a number of localities in the State and the nation, such as are given for Urbana in the last two columns of Table V.

Having this information, one will be able to compute the date when a certain event in the seasonal history of an important insect will occur at one place if the date when it occurred at another place is known.

It will be seen that there are many ways in which a knowledge of the significance of day-degrees of effective temperature and their accumulation as the season progresses can be of use to the practical orchardman or to the entomologist, especially in enabling him to forecast the dates when larvae of the several generations will begin to hatch, and when hatching will be at its height.

The accumulated day-degrees alone may be depended upon in forecasting the date when the sprays should be applied, or they may be used in connection with observations as illustrated earlier in the paper, as they have been used in Illinois for the last few years in forecasting the dates when sprays should be applied for the first larvae of the different broods.

It is of interest to note how accurately an event may be forecast by the use of accumulated day-degrees of effective temperature. While data were being collected for this study at Olney, Illinois, in 1915, 1916, and 1917, accurate observations were made on the dates when the first larvae of the three generations hatched as compared with the forecast or theoretical dates when they should have hatched.

Observations at Olney

Generation	Year	Theoretic date	Observed date	Difference in days
First	1915	May 15	May 17	2
First	1916	May 24	May 25	1
First	1917	May 31	June 2	2
Second	1915	July 11	July 11	0
Second	1916	July 10 or 11	July 11	1
Second	1917	July 18	July 17	1
Third	1915	Aug. 23	Aug. 29	6
Third	1916	Aug. 18	Aug. 20	2

Observations at Urbana

Generation	Stage	Year	Theoretic date	Observed date	Difference in days
Hibernating	1st adult	1924	May 28	May 30	2
Hibernating	1st adult	1925	May 6	May 9	3
First	1st larvae	1926	June 6	June 3–5	1 to 3
First	1st adult	1926	July 15	July 9	6
First	1st adult	1927	July 13	July 15	2
Hibernating	1st adult	1928	May 16	May 20	4
First	1st adult	1928	July 11 or 12	July 13	1 or 2
Hibernating	1st adult	1929	May 12	May 12	0
First	1st larvae under band	1929	June 24	June 26	2
Hibernating	1st adult	1930	May 4	May 5	1

The differences between the predicted, or theoretic dates, based on accumulated day-degrees of effective temperature and the actual dates on which the events were observed to occur are remarkably small, and as observations may not always be accurate, especially if they are not made systematically, the discrepancies above recorded may be more the result of faulty observations than of methods of determining the theoretic dates.

Dr. T. J. Headlee, State Entomologist of New Jersey, in his report for the year ending June 30, 1929, makes the following statement with respect to climate and insect investigations:

"The thermal constant method of determining when codling moth sprays should be applied was carried through the fiscal year, and its accuracy for this purpose was amply demonstrated. By actual comparison of the theoretic dates indicated by it with the actual dates shown by codling moth emergence boxes, it was found that as a rule a difference of not to exceed one day existed between them. The number of temperature stations in 1928 was 38, whereas in 1929 the number was reduced to 7. This reduction was made because smaller numbers gave as good an indication as the larger number and cost much less to maintain."

It will be possible for any one who keeps temperature records such as are described in this paper to learn by observation the number of effective day-degrees which has accumulated on any date on which an important event in the seasonal history of the codling moth may occur, and by recording these he may be able to anticipate their approach every year, however early or late the season may be.

Thus far this discussion has been confined to the use of accumulated day-degrees of effective temperature to forecast the time of the appearance of different events in the seasonal history of the codling moth. Observations made during the past few years indicate that the same temperature factors may be of use to forecast the time of appearance of a number of other insects.

The following insects may be expected to begin to appear when the number of day-degrees of effective temperature placed after their names have accumulated:

Insect	Day-degrees		Day-degrees	
Chionaspis furfura	Young of 1st brood	275;	young of 2nd brood	1500
Chionaspis americana	Young of 1st brood	275;	young of 2nd brood	1500
Chionaspis pinifoliae	Young of 1st brood	275;	young of 2nd brood	1500
Lepidosaphes ulmi (double brooded form)	Young of 1st brood	275;	young of 2nd brood	1500
Lepidosaphes ulmi (single brooded form)	First young	450;		
Aspidiotus perniciosus	Young of 1st brood	725;	young of 2nd brood	2110
Pulvinaria vitis	First eggs	550;	1st young	850
Gossyparia spuria			First young	843
Hemerocampa leucostigma	Larvae of 1st brood	300;	larvae of 2nd brood	1400
Thyridopteryx ephemeraeformis			1st young	575

Further studies will undoubtedly show that the limits of the temperature zones vary for different species of insects and thorough studies of the relationship between insects and temperatures will give us more accurate means of forecasting their appearance and development. Judging from the few observations which have been made on other insects, however, the effective temperatures as worked out for the codling moth may be applied to other insects whose life cycles are comparable to that of the codling moth whose rate of development is not affected to any large degree by humidity or other factors.

Accumulative temperatures based on atmospheric conditions cannot be depended upon to indicate when insects which hibernate under ground will emerge from hibernation, but for many insects that spend their entire lives in the open, the same temperature units of effective day-degrees as have been worked out for the codling moth may be found accurate enough for ordinary forecasting.

In conclusion, the writer wishes to express the hope that greater attention may be given to the relations of climate to insect development, being confident that these relations are sufficiently constant to be of great practical value.